ROCK CHARACTERISTICS IMPORTANT IN REPOSITORY SITING

4.26 Introduction

All rocks are not created equal. Two rocks may look alike yet be very different in many ways. So, the characteristics of the rock at any site are carefully evaluated in determining whether that site is suitable for a repository. In addition, the design of the waste disposal container and the repository itself will take the characteristics of the host rock into account.

Are all rocks the same?

It is important to realize that while no rock is perfect in all ways, strengths in one characteristic may compensate for weaknesses in another. Also, remember that a rock is simply a combination of individual minerals that have properties. Taken together, the properties of all the individual minerals yield the rock characteristics.

What determines the characteristics of a rock?

4.27 Characteristics Important for Mining and Mine Safety

A repository is first and foremost a special mine. Rock properties that make mine construction safe and reasonably easy are important. One key property is *compressive strength.* Rocks with high compressive strength resist breaks or fractures even when stressed or "squeezed."

What characteristics contribute to mine safety?

4.28 Technical Questions

4.28a Rock Mechanics

The reaction of the rock to the heat produced by the nuclear waste is the major concern. How well does the rock move or conduct heat away from the fuel? How does the rock react to heat physically? How does heat affect the rock chemistry?

What is the early technical concern?

What is the concern later on?

Over the very long periods of time required for high-level waste disposal, there will be much less heat. But rock properties that contribute to waste isolation continue to be vital. Numerous rock characteristics can work to prevent or slow movement of fluids (either gases or liquids) that might be carrying wastes. For example, how much empty space is there in the rock that fluids can get into? (How porous is the rock?) How hard or easy is it for fluids to flow through, or permeate, the rock? What physical or chemical rock properties might slow the movement of the waste?

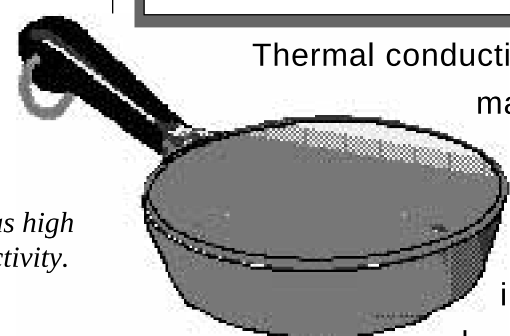
4.28b Rock Characteristics Related to Heat

What properties are related to how heat affects a rock?

Rock characteristics that have something to do with how a rock responds to heat include *thermal conductivity*, *plasticity*, and *thermal stability*.

Thermal Conductivity

What is thermal conductivity?



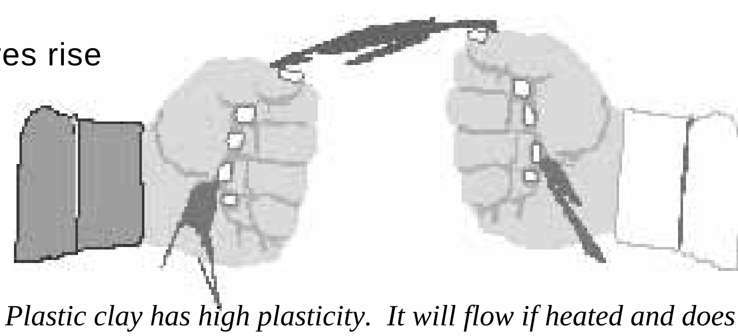
A frying pan has high thermal conductivity.

Thermal conductivity is a measure of how well any material will transmit or move heat. A well-made cooking pan transmits the heat from the burner very well, while the attic insulation in your house is very inefficient at transmitting heat from the house to outdoors in winter. Most rocks are better insulators than conductors. They tend to let heat and temperatures build up near a heat source (such as buried waste). They lose heat slowly.

Plasticity

What is plasticity?

If temperatures rise enough, the strength of the host rock can be affected. We usually think of rocks



Plastic clay has high plasticity. It will flow if heated and does not break easily. However, it will break if pulled too far.

as solids. However, at elevated temperatures and pressures, rocks will actually flow, though at slower rates than water, mud, or clay. The term for this property is plasticity. Plasticity may have both advantages and disadvantages. During flow, fractures in rocks may be closed. However, if pushed too far, too fast, the rock may develop cracks that do not seal. This can affect the strength of the rock. At a repository, it could also make safe retrieval of waste more difficult.

Why is plasticity important?

Thermal Stability

Many minerals in the rock may be changed by exposure to heat. How much change there is depends on the mineral in question. Minerals such as zeolites and clays give off water when heated and their ion exchange properties change, usually decreasing. Water circulation through the rock is an effective way to conduct heat away from the repository. Also, the solubility of minerals may increase or decrease in heated water.

How can heat affect the minerals that make a rock?

4.28c Rock Characteristics Related to Flow of Gases or Liquids

Numerous rock characteristics will work to prevent or slow the flow of fluids—either gases (air) or liquids (ground water). Some key characteristics related to the flow of fluids in rocks are sorptive capacity, porosity, permeability, effective porosity, and solubility.

What rock characteristics are related to flow of air or liquid?

Sorptive Capacity

Sorption is a process for removing dissolved material from solution by “attaching” the dissolved solids to the surface of another solid. Sorptive capacity of a rock is a measure of the ability of its surfaces to remove dissolved material from solutions passing through the rock, by sorption. The sorptive capacity of the rock will work to limit waste movement.

What is sorption?

Sorptive capacity includes both chemical and physical processes. The chemical processes include all those mechanisms that can take atoms or molecules of waste and attach them to rock (mineral) surfaces. An example of a chemical process of sorption is *ion exchange.* In ion exchange, particles with an electrical charge (ions) in water change places with ions that were attached to a mineral called a zeolite. The waste ions are removed from the water and harmless ions go into the water.

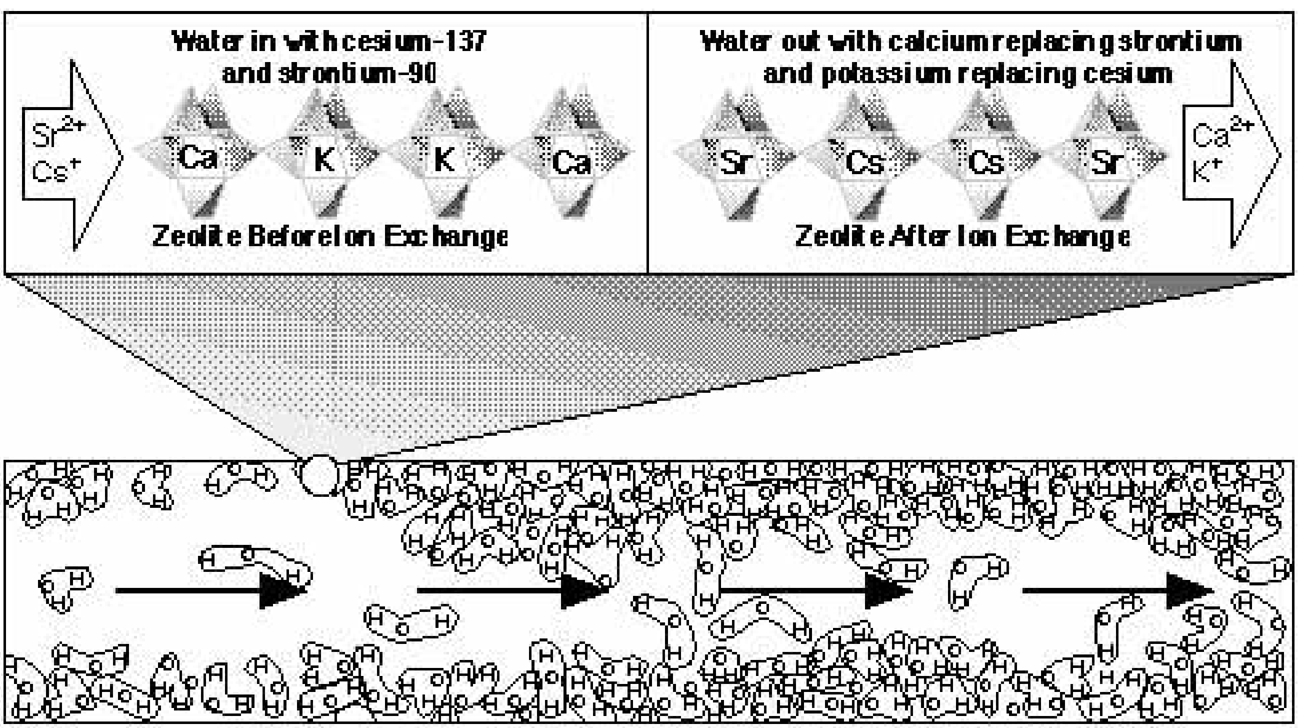
What is ion exchange?

Many people are familiar with ion exchange because it is the chemical process used in water softening devices to remove unwanted minerals from "hard" water in many sections of the country.

A physical sorption process might be the physical trapping of water molecules in small pores. In these small pores, water molecules are stuck between the molecule and the wall of the pore.

Sorptive Process

Chemical sorption: As a result of the chemical process of ion exchange, cesium-137 (Cs) and strontium-90 (Sr) may attach to a zeolite, which is a part of the pore wall structure. The replaced calcium (Ca) and



Physical sorption: In physical sorption, water molecules in small pores are immobilized due to frictional forces between the molecule and the pore wall, in effect decreasing the size of the pore.

Porosity and Permeability

What are porosity an permeability?

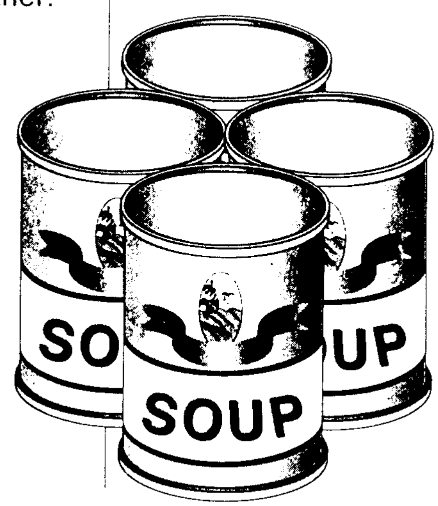
Are they related?

Porosity and permeability are related but different. *Porosity* is a measure of the ability of anything, in this case a rock, to hold a fluid. Strictly, it is the ratio of open space in a volume of rock divided by the total volume of the rock (open space plus solids).

$$\frac{\text{Volume of pores}}{\text{Total rock volume}} \times 100 = \text{porosity (\%)}$$

The open spaces in all rocks are filled with a fluid from the time of rock formation. Most porous rocks were formed by individual particles that settled out of suspension in sea water. Over time periods ranging from a few years to a few million years, the particles cemented together to form a rock. Formation of the rock may reduce the amount of porosity, but it does not completely eliminate porosity. The pore spaces in rocks formed in this way are filled with sea water. The type of rock being studied in Nevada to see if it will be suitable for a repository is *tuff.* The particles that make up a tuff rock formation are often deposited on land. The particles settle out of the atmosphere after a volcanic eruption. The pore spaces between particles are filled with air at first. The air may be replaced by fresh water as rain flows through the pores that are connected to one another.

Permeability is a measure of the ease of flow of a fluid through a porous solid. The important connection between porosity and permeability is just that: connection. If the pores are not connected, fluid cannot flow between pores and out of the rock. For example, think of a grouping of unopened soup cans. Porosity (the ratio of fluid holding volume to total volume) is very high. But without connections between the "pores," in this case, cans, there is no flow. Permeability is zero.



Unopened soup cans have very high porosity, but because there are no connections between "pores," there is no flow. Permeability is zero.

Rocks can have porosity, but if the pores are so small that you have difficulty pushing a fluid through, the rock has essentially no permeability. On the other hand, a rock containing a few wide open cracks may have a low calculated porosity, but a high permeability.

Effective Porosity

What is effective porosity?

All rocks have porosity and permeability. But in some cases, the values for these properties are so very small that we say the rocks are non-porous and impermeable. Sometimes a rock is described as having effective porosity that is less than its true porosity as defined earlier. Effective porosity considers only those pores that are connected and large enough to permit fluid flow. In other words, only the fraction of total porosity that contributes to the permeability is considered when evaluating effective porosity.

Solubility

What is solubility?

Solubility is a measure of the tendency for a solid to dissolve. If the minerals making up the rock of the repository site are soluble and will dissolve, such as in a salt formation, movement of water may open larger pores and make connections between pores. This creates porosity and enhances permeability.

What factors determine solubility?

Can solubility change?

Solubility depends on properties of both the solid and the liquid. For example, table salt (NaCl) is very soluble in fresh water, less soluble in sea water, and even less soluble in Great Salt Lake water. It is practically insoluble in pure alcohol (isopropyl alcohol). In any rock, some minerals will be more soluble or less soluble than others for any given solution passing through. A point to remember—as the minerals dissolve, the composition of the solution changes. Its ability to dissolve more of the same or other minerals also changes, usually decreasing. Tuff, the host rock at Yucca Mountain, has a very low solubility factor. At some point, the solution cannot dissolve any more minerals because it is completely saturated.

4.29 Tuff

What is tuff?

The host rock at the site being studied to see if it is suitable for a repository is described as a “welded and devitrified” tuff. What do those words mean in terms of the rock characteristics important in repository siting?

Tuff is formed when a volcano erupts and throws a cloud of hot, small particles of molten rock into the air. As the particles cool and become solid, they fall back to the ground. There they accumulate as a layer called an "ash-fall tuff." Sometimes, the particles in the cloud are so numerous that the cloud acts more like a fog that doesn't rise very much above the volcano summit before it starts to flow down the slope. As it flows, the melt droplets cool and solidify, and the particles fall to the ground to accumulate as a layer of ash-flow tuff.

How is the tuff formed?

Welded Tuff

What is a welded tuff?

Depending on the thickness of the layer and how much the particles cooled while falling, the layer will retain greater or lesser amounts of heat. Just as a human welder uses heat to connect two pieces of metal, the heat and the weight of overlying material will weld the individual particles together. The result is a welded tuff. It is denser (less porous) and stronger than a non-welded tuff. The welding process gives the tuff strength (important in mining) and reduces the original porosity and permeability.

Rapid Cooling of Liquid Rock

How does rapid cooling affect the rock that forms?

When molten tuff is thrown out of a volcano and exposed to the atmosphere, the masses of liquid rock cool rapidly. The atoms that will form into minerals in the rock particles cannot move very far before the melt cools and becomes solid. There isn't much time to form a few larger mineral crystals, so lots of very small, almost invisible crystals form. Most of the atoms in the melt may not have time to form even minute crystals. They are frozen in place by the rapid cooling. The cooled rock particles have a glass-like appearance because crystals didn't have time to form or they are too few and too small to be seen.

Volcanic Glass

How does devitrification affect volcanic rock?

Volcanic glass is unstable when exposed to ground water and atmospheric gases. The glassy material reacts with water. Through a complex process called *devitrification,* the atoms in the glass are rearranged into minerals like zeolites and cements (opal or calcite). Ion exchange capacity increases. Porosity and permeability decrease. New minerals formed from the volcanic glass contain large amounts of water and are bulkier than the original glass. They fill up more pore space and make the interconnections smaller. Most of the minerals formed during devitrification are not soluble in water. However, they tend to give off water and lose ion exchange capacity when exposed to heat.

4.30 Rock Characteristics and the Overall Repository Design

How do rock properties fit into the overall design for safety?

Selecting a site for a <u>repository</u> requires consideration of the properties of the host rock in which the <u>repository</u> will be located. The characteristics of the host rock at the <u>repository</u> will be considered, not only in the design of the repository as a mine, but also in relation to its special purpose of safely isolating waste from the environment. As important as rock characteristics are, the host rock is only one part of a multiple barrier system required for the disposal system. The barriers will be both natural and engineered (manmade). The multiple barrier system consists of 1) the waste package (manmade), 2) the repository itself (manmade), and 3) the host rock (natural). The total system will be designed so that the parts of the multiple barrier system work together to maximize safety.